Research Article

Seed Germination Response of Chickpea Varieties to Different Chemical Applications

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Abstract | The laboratory experiments were conducted at Department of Weed Science and Botany, The University of Agriculture Peshawar, during the studied year 2022 and 2023. Using completely randomized design (CRD) with factorial arrangement having three replications. A comparative study was conducted using three chickpea varieties designated as Factor-A (Fakhre Sehra, Chattan, and KK-1) and Factor-B comprising chemical treatments at a 12 mM concentration each, including Sodium azide (NaN_3), Stomp 330 EC (Pendimethalin), and Puma super 7.5%EW (Fenoxaprop-p-ethyl), with deionized (control). Growth parameters considered included germination (%), shoot length plant^{-1} (cm), root length plant^{-1} (cm), seedling fresh weight (mg) and seedling dry weight (mg). Two-year experimental outcomes revealed significant differences ($P \leq 0.01$) in growth parameters across treatments and varieties. Among chemical treatments, Sodium azide exhibited higher performance with maximum values for germination (95 %), shoot length plant^{-1} (6.78 cm), root length plant^{-1} (11.78 cm), seedling fresh weight (79.23 mg), and dry weight (15.83 mg). In contrast, Stomp 330 EC treatment indicated the lowest values across all parameters: germination (76.11%), shoot length plant^{-1} (4.71 cm), root length plant^{-1} (8.99 cm), seedling fresh weight (67.06 mg), and dry weight (11.44 mg). Among varieties, Fakhre Sehra revealed best performance with highest mean values for germination (93.80%), shoot length plant^{-1} (6.69 cm), root length plant^{-1} (11.44 cm), seedling fresh weight (78.59 mg), and dry weight (15.51 mg). Conversely, KK-1variety exhibited minimal performance with lowest values in germination (83.80%), shoot length plant^{-1} (5.88 cm), root length plant^{-1} (10.62 cm), seedling fresh weight (74.81 mg), and dry weight (13.83 mg). The study concluded that sodium azide was the most effective in improving seedling growth parameters, and that the 'Fakhre Sehra' variety performed better than the other varieties that were studied. These outcomes offer important information for improving chickpea farming methods in order to increase production and decrease the adverse impacts of herbicides on chickpea.

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Keywords | Chickpea, Germination (%), Puma super 7.5%EW, Sodium azide, Stomp 330 EC, Shoot length plant^{-1} (cm).

Introduction

Chickpea (*Cicer arietinum* L.), a member of the Fabaceae family, a significant cool winter legume crop cultivated in many countries, and geographical areas around the world (Kanatas and Gazoulis, 2022). In addition to being a significant source of rich in nutrients protein for humans, its ability to fix nitrogen makes it an essential factor of soil fertility management. Chickpeas are noted for being high in protein (15-22%), dietary fiber, carbohydrate, minerals, and vitamins (Dutta *et al*., 2022; USDA, 2021). For vegetarians, legumes like chickpeas offer a simple and affordable protein source (Rastogi *et al*., 2021). Chickpeas are classified into two main types based on seed morphology: Desi and Kabuli. Desi chickpeas have small, black seeds, while Kabuli chickpeas have larger, smoother, and lighter-colored seeds (Vus *et al*., 2020). Chickpeas are cultivated in more than forty countries globally (Soomro *et al*., 2021), with India, Pakistan, Turkey, Australia, and Myanmar leading in chickpea production (FAOSTAT, 2021.). Regarding productivity, chickpeas come second only to beans (*Phaseolus vulgaris* L.) among vital food legumes. Chickpeas contribute roughly 12% to global pulse production, with Asian nations responsible for over 70% of the crop (Aswathi *et al*., 2019; Kushwah *et al*., 2021). In Pakistan, during the 2023-2024 crop year, chickpea cultivation covered 0.940 million hectares, yielding almost 0.54 million metric tonnes. Specifically, in the province of Khyber Pakhtunkhwa, 18600 tonnes of chickpeas were produced on 29000 ha of land, achieving an average grain yield of 643 kg ha^{-1} (Pakistan Economic Survey, 2023-2024). Khyber Pakhtunkhwa emerges as the leading region in Pakistan for chickpea cultivation among pulse crops. However, in contrast to other chickpea-producing nations, Pakistan's average yield of such pulses is remarkably low. The primary factors contributing to this low chickpea production in Pakistan include soil with insufficient organic matter, nutrient deficiencies, inadequate tillage practices, and ineffective weed management practices (Dubey and Prakash, 2023). Improving chickpea yield production can be achieved by adopting advanced agricultural technologies, utilizing resistant and high-yielding varieties, and implementing effective weed control measures. Some chickpea varieties may rarely facilitate the growth of different weed species. Whereas certain varieties can endure weed infestations, others may be more susceptible to them (Rasool *et al*., 2024). Moreover, herbicide residues from various chemical weed control methods have been found to adversely affect the nodulation of susceptible chickpea varieties and their yield components (Iqbal *et al*., 2021). However, the careful and appropriate use of recommended herbicides has effectively mitigated yield losses due to weeds and has resulted in increased grain yield for legume crops, including chickpeas (Khan *et al*., 2023). "Dormancy" is a characteristic found in chickpea seeds, describing the conditions required for the seed to germinate (Weldemichael *et al*. (2021). Some chemicals have been investigated in various studies aimed at enhancing the growth and yield of chickpea (Ahmad *et al*., 2019). Reports have documented the efficacy of sodium azide at different concentrations on a chickpea seeds. The application of sodium azide led to an increase in chickpea crop-related traits, suggesting a valuable effect on plant growth, and development. Sodium azide treatment has the potential to improve overall growth and vigor in chickpea plants, thereby enhancing crop traits. Dormancy presents itself in various forms, and understanding it is a critical subject for environmental sustainability (Akinyosoye *et al*., 2021; Srivastava *et al*., 2019). The objectives of the study were to assess the comparative resistance of different chickpea varieties to sodium azide and herbicides, and to evaluate the inhibitory effects of these chemical treatments on seedling growth parameters of chickpea varieties.

Materials and Methods

Plant materials

Three certified chickpea varieties (Fakhre Sehra, Chattan, and KK-1), were obtained from the Gram Research Station Ahmad Wala in Karak (33°N, 71°E). Subsequently cleaning, the seeds were placed in paper bags, and kept at a temperature of 25°C, for later use in experimental work.

Laboratory description

The experiment was conducted over two consecutive winter seasons (November-December 2022 and November-December 2023) under similar laboratory conditions, at the Department of Weed Science and Botany Research Lab, the University of Agriculture Peshawar.

Experimental setup and application of chemical treatments

The experiment used sterilized petri dishes (9 cm diameter, autoclaved at 110-120°C for 1 hour) lined with dual filter papers. Ten seeds of each chickpea variety (Fakhre Sehra, Chattan, and KK-1) were placed in each petri dish for germination. The experiment was carried out using a completely randomized design, with factorial arrangement having three replications. To assess the potential of three chickpea varieties (Fakhre Sehra, Chattan and

KK-1), four treatments were applied at a 12 mM concentration each, including Sodium azide (NaN_3), Stomp 330 EC (Pendimethalin), Puma super 7.5%EW (Fenoxaprop-p-ethyl), and deionized water (control). Selected viable chickpea seeds were treated with 12 mM solutions of each treatment using a mini sprayer on days 1, 3, and 9, with succeeding moisture maintenance using deionized water. Data was monitored over a four-week period.

Recorded parameters

Seedling growth parameters were assessed following standardized protocols. The germination (%) was determined by using the formula:

$$\text{Germination (\%)} = \frac{\text{Germinated seeds}}{\text{Total number of seeds}} \times 100$$

Measurements of vegetative growth parameters were evaluated, including shoot length plant^{-1} (cm), root length plant^{-1} (cm), seedling fresh weight (mg), and seedling dry weight (mg).

Statistical analysis

The ANOVA procedure, appropriate for a completely randomized design, with factorial arrangement, Statistix 8.1 software was used to analyzed the experimental data that was collected. LSD tests were carried out in accordance with Steel *et al.* (1997), when the F value was determined to be significant.

Results and Discussion

Germination (%)

The combined year analysis demonstrated significant differences ($P \leq 0.01$) in chickpea seed germination (%) among various chemical treatments. The analysis showed that the impact of the year on the observed results was statistically non-significant (Table 1). The control (deionized water) treatment had the highest mean germination (97.22%), which was statistically similar to the sodium azide (95 %). In contrast, pendimethalin had the lowest mean germination (76.11%). Moreover, among the chickpea varieties, the highest mean germination percentage was documented for the Fakhre Sehra (93.8%) variety, while the smallest for KK-1 (83.8%) variety, which were statistically different from each other. There was a statistically significant interaction between treatments and varieties in terms of germination percentages. Analysis of this interaction showed that the maximum germination occurred with the combination of sodium azide and the Fakhre Sehra variety, however the lowest germination was documented with the use of pendimethalin in conjunction with the KK-1 variety (Figure 1). These results support with those of Tanveer *et al.* (2010) stated on the influence of herbicide use on chickpea germination percentage. Further indication is provided by Molaie *et al.* (2017), who exhibited that although herbicides are an excellent way to control weeds, they can cause serious phytotoxicity in chickpeas. Similar to Iqbal *et al.* (2021), who found minimal germination percentage with Stomp 330 EC. In contrast, the positive effects of sodium azide observed in our study align with Maluszynski *et al.* (2009) who stated that indicating its mutagenic potential for improving economic traits across various crops. These positive consequences are constant with Khan *et al.* (2011) observations of chickpea tolerance to sodium azide and El Kaaby *et al.* (2015) results of improved germination percentage in sodium azide-treated tomato varieties. The finding of this study revealed that herbicide treatments, while effective for weed control, adversely affect crop development by interfering with nutrient movement in emerging crop seedlings.

Table 1: *Influence of various chemicals on seed germination (%) of chickpea varieties*

Treatments	Chickpea varieties			Treatments mean
	Fakhre sehra	Chattan	KK-1	
Sodium azide (NaN_3)	98.3 a	98.3 a	88.3 bc	95 a
Stomp 330 EC (Pendimethalin)	86.7 bc	75.0 d	66.7 d	76 c
Puma super 7.5%EW (Fenoxaprop-p-ethyl)	91.7 abc	86.7 bc	85.0 c	88 c
Deionized water (Control)	98.3 a	98.3 a	95.0 ab	97 a
Varieties mean	93.8 a	89.6 b	83.8 c	
Year 2022 year 2023				88.989.2
LSD $_{(0.01\%)}$NS				
Interactions year × varieties year ×treatments varieties ×treatments				Significance NS NS*

LSD for varieties (0.01%) = 3.26

LSD for treatments (0.01%) = 4.14

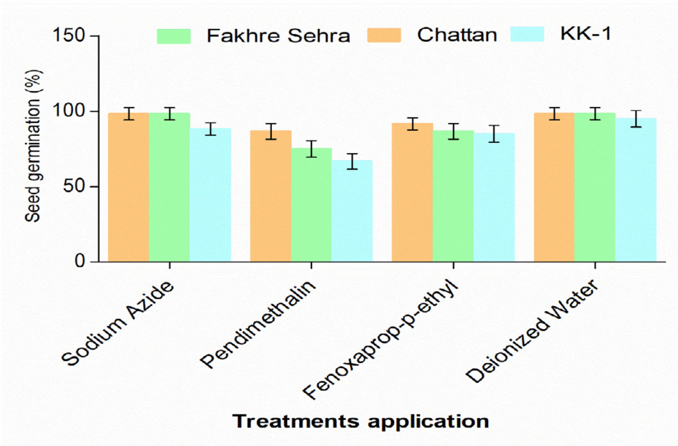

Figure 1: *Interaction of varieties and treatments on germination (%) of chickpea.*

Shoot length plant^{-1} (cm)

The statistical analysis of the combined year exhibited that the different chemical treatments had substantial variances ($P \leq 0.01$) in the shoot length (cm) of chickpea varieties. The impact of the year on the observed outcomes was determined to be statistically non-significant (Table 2). Treatment differences revealed that control treatments (deionized water) produced the maximum shoot length (7.51 cm), which was followed by sodium azide (6.78 cm), whereas pendimethalin application resulted in the smallest shoot length (4.71 cm). Moreover, among the varieties, Fakhre Sehra achieving the maximum shoot length (6.69 cm) and KK-1 showing the smallest shoot length (5.88 cm) under various chemical treatments. The interaction between treatments and varieties, the maximum shoot length was noted with the combination of sodium azide treatment and the Fakhre Sehra variety. In contrast, the lowest shoot length was documented when pendimethalin was used in conjunction with the KK-1 variety (Figure-02). According to current results, the control and sodium azide treatments produced longer shoots, while stomp 330 EC produced the smallest shoot. Furthermore, the chickpea varieties were found to contrast in shoot length, with Fakhre Sehra showing the longest shoots in comparison to Chattan and KK-1 varieties. Amin *et al.* (2006) who described that the application of herbicides could have adverse effects on crop growth and development, especially with regard to shoot length. Veisi *et al.* (2019) also exhibited that herbicides can have a substantial adverse impact on the shoot length of chickpea plant. In contrast, El Kaaby *et al.* (2015) stated that the use of sodium azide had potential effect on enhancing shoot length. Present study also in line with Al-Qurainy (2009) who reported that the shoot length of *Eruca sativa*, was enhanced, using a sodium azide concentration of 3mM. The revealed inhibition of shoot development under herbicide treatments highlighted major challenges in legumes crop. These conclusions contribute important understandings for developing sustainable weed management strategies that balance effective weed control with crop safety to sustain agricultural productivity and food security.

Table 2: *Influence of various chemicals on shoot length plant^{-1} (cm) of chickpea varieties*

Treatments	**Chickpea Varieties**			**Treatments Mean**
	Fakhre Sehra	Chattan	KK-1	
Sodium azide (NaN_3)	7.15 c	6.74 d	6.45 de	6.78 b
Stomp 330 EC (Pendimethalin)	5.47 f	4.43 g	4.23 g	4.71 d
Puma super 7.5%EW (Fenoxaprop-p-ethyl)	6.36 e	5.69 f	5.64 f	5.90 c
Deionized water (Control)	7.79 a	7.51 ab	7.23 bc	7.51 a
Varieties mean	6.69 a	6.09 b	5.88 c	
Year 2022 Year 2023				6.21 6.23
LSD $_{(0.01\%)}$				NS
Interactions year × varieties year ×treatments varieties ×treatments				Significance NS NS *

LSD for varieties (0.01%) = 0.13
LSD for treatments (0.01%) = 0.16

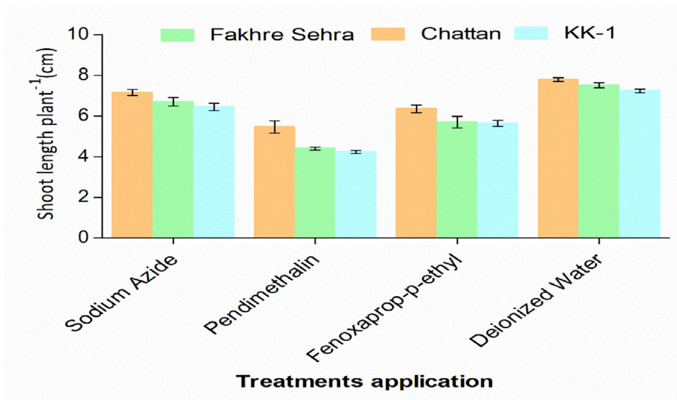

Figure 2: *Interaction of varieties and treatments on shoot length plant^{-1}(cm) of chickpea.*

Root length plant^{-1} (cm)

The combined year analysis exhibited significant variances ($P \leq 0.01$) in root length plant^{-1}(cm) among chickpea varieties under various chemical treatments. The impact of the year on the observed results was considered statistically non-significant (Table 3). Regarding treatments analysis showed that the highest mean root length (12.51 cm) was recorded for the control treatment, that was followed by sodium azide (11.78 cm). In contrast, the lowest root length (8.99 cm) was documented in pendimethalin treatments. Similarly, among the chickpea varieties, the highest mean root length (11.44 cm) was noted for the Fakhre Sehra variety. Conversely, the KK-1 variety revealed the minimum root length (10.62 cm). The interaction between treatments and chickpea varieties indicated that the maximum root length was recorded for sodium azide × Fakhre Sehra, while the lowest root length was recorded for pendimethalin × KK-1 variety (Figure 3). There is lots of indication representing the detrimental effects of herbicide application on root development of crops. Amin *et al*. (2006) emphasized the disruption of nutrient movement and subsequent inhibition of crop root development. Veisi *et al*. (2019) stated that in agricultural systems, the probability that herbicides will result in reduced root development is a serious concern. In contrast, studies showed by El Kaaby *et al*. (2015) and Al-Qurainy (2009) exhibited that sodium azide has the ability to stimulate root length in *Eruca sativa* and chickpea plants. This is in line with the perspective of Khan *et al*. (2009) about sodium azide as an intended mutagenesis technique to enhance agronomic hereditary traits. These deviating research findings highlighted the critical need for judicious chemical management in agricultural systems. Developing integrated weed management practices that balance minimal herbicide requirement with strategic mutagenic treatments could provide a more sustainable pathway for crop improvement and agricultural productivity.

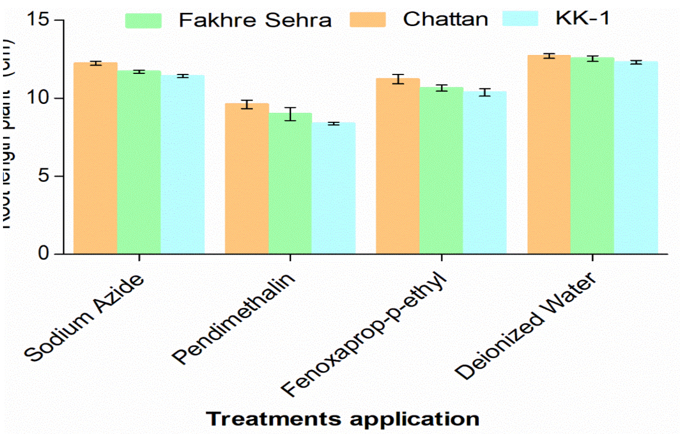

Figure 3: *Interaction of varieties and treatments on root length plant^{-1}(cm) of chickpea.*

Table 3: *Influence of various chemicals on root length plant^{-1} (cm) of chickpea varieties*

Treatments	**Chickpea varieties**			**Treat-ments mean**
	Fakhre sehra	Chattan	KK-1	
Sodium azide (NaN_3)	12.24 b	11.70 c	11.42 cd	11.78 b
Stomp 330 EC (Pendimethalin)	9.61 f	8.99 g	8.37 h	8.99 d
Puma super 7.5%EW (Fenoxa-prop-p-ethyl)	11.22 d	10.65 e	10.37 e	10.75 c
Deionized water (Control)	12.70 a	12.54 ab	12.30 ab	12.51 a
Varieties mean	11.44 a	10.97 b	10.62 c	
Year 2022 Year 2023				11.02 11.00
LSD $_{(0.01\%)}$				NS
Interactions yyear × va-rieties year ×treatments varieties ×treatments				Signif-icance NS NS

LSD for varieties (0.01%) = 0.15
LSD for treatments (0.01%) = 0.20

Table 4: *Influence of various chemicals on seedling fresh weight (mg) of chickpea varieties*

Treatment	**Chickpea varieties**			**Treat-ments mean**
	Fakhre sehra	Chat-tan	KK-1	
Sodium azide (NaN_3)	81.03 d	78.78 e	77.88 e	79.23 b
Stomp 330 EC (Pendimethalin)	69.00 i	66.60 j	65.59 j	67.06 d
Puma super 7.5%EW (Fenoxa-prop-p-ethyl)	75.80 f	73.42 g	71.89 h	73.70 c
Deionized water (Control)	88.52 a	85.41 b	83.90 c	85.94 a
Varieties mean	78.59 a	76.05 b	74.81 c	
Year 2022 year 2023				76.37 76.59
LSD $_{(0.01\%)}$				NS
Interactions year × va-rieties year ×treatments varieties ×treatments				Signif-icance NS NS*

LSD for Varieties (0.01%) = 0.38
LSD for Treatments (0.01%) = 0.48

Seedling fresh weight (mg)

The combined year analysis indicated significant differences ($P \leq 0.01$) in seedling fresh weight (mg) among chickpea varieties under various treatments.

Whereas the impact of the year on the observed results was measured statistically non-significant (Table 4). Regarding treatments, the maximum mean seedling fresh weight (85.94 mg) was recorded for the control treatment, which was followed by sodium azide treatment (79.23 mg). In contrast, the lowest seedling fresh weight (67.06 mg) was documented in pendimethalin. Similarly, among the chickpea varieties, the maximum mean seedling fresh weight (78.59 mg) was noted for the Fakhre Sehra variety. However, the KK-1 variety revealed the minimum seedling fresh weight (74.81 mg). The interaction between treatments and chickpea varieties showed that the maximum seedling fresh weight was recorded for sodium azide × Fakhre Sehra, while the least seedling fresh weight was documented for pendimethalin × KK-1 variety (Figure 4). The conclusions of the study highlighted the significant impact that treatment and chickpea varieties have on seedling fresh biomass. Dubey *et al.* (2018) described that herbicides adversely affect chickpea development, with symptoms including stunted growth, leaf yellowing, and possible plant death. Moreover, Amin *et al.* (2006) and Veisi *et al.* (2019) described that the use of herbicides can cause severe toxic responses in chickpea seedlings. Conversely, current studies also support Khan *et al.* (2009) stated that sodium azide increased fresh weight in contrast to control treatments. Moreover, Srivastava *et al.* (2019) stated that an increase in sodium azide dosage led to a rise in seedling fresh weight. A number of factors, such as the particular plant species, growing period, and environmental conditions, affect the relationship between sodium azide concentration and seedling fresh biomass. These results highlighted the need to prudently consider the effects of chemical applications on crop growth patterns. Herbicide use can have adverse impacts, namely toxicity to plants, even if sodium azide treatments may improve plant development. Farmers may find that comprehensive weed control strategies that use fewer herbicides and include a variety of weed management techniques help to reduce adverse effects and boost sustainable agriculture techniques.

Seedling fresh weight (mg)

The combined year analysis demonstrated significant variations ($P \leq 0.01$) in seedling dry weight (mg) among different chickpea varieties subjected to various chemical treatments. While the year impact on the observed outcomes was statistically non-significant (Table 5). Analysis showed that data regarding treatments, the highest mean seedling dry weight (17.53 mg) was recorded for the control treatments, that was followed by sodium azide treatment (15.83 mg).

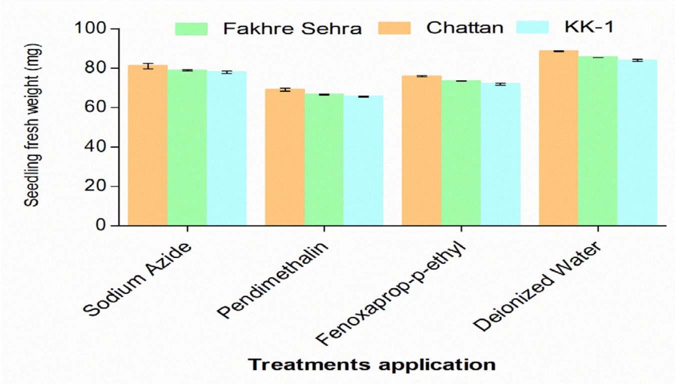

Figure 4: *Interaction of varieties and treatments on seedling fresh weight (mg) of chickpea.*

Conversely, the lowest seedling dry weight (11.44 mg) was noted for pendimethalin application. Similarly, among chickpea varieties, the Fakhre Sehra variety exhibited the highest mean seedling dry weight (15.51 mg). Conversely, the KK-1 variety revealed the lowest seedling dry weight (13.83 mg). The interaction between treatments and chickpea varieties revealed that utmost seedling dry weight was recorded for sodium azide × Fakhre Sehra, while the lowest seedling dry weight was documented for pendimethalin × KK-1 variety (Figure 5). Herbicides and sodium azide have been revealed that diverse impacts on plant development. The detrimental effects of herbicides on chickpea production have been revealed in studies with growth suppression, yield reduction, and plant toxicity by Dubey *et al.* (2018); Amin *et al.* (2006); Veisi *et al.* (2019). In contrast, Khan *et al.* (2009) and Al-Qurainy (2009) stated that plants treated with sodium azide had a higher dry weight than control treatments, suggesting that the treatment had a useful impact on plant development. These outcomes are further sustained by Srivastava *et al.* (2019) stated that increasing the dosage of sodium azide enhanced the dry biomass of the seedlings, although noting that there may be variability depending on plant type and environmental conditions. By summarizing these conclusions, highlighted the importance of accepting the differential effects of chemical treatments on crop development. This information can inform more sustainable agricultural practices and help mitigate potential negative impacts on crop productivity and health.

Table 5: *Influence of various chemicals on seedling dry weight (mg) of chickpea varieties*

Treatments	Chickpea varieties			Treatments mean
	Fakhre Sehra	Chattan	KK-1	
Sodium azide (NaN_3)	16.4 c	15.7 d	15.4 d	15.828 b
Stomp 330 EC (Pendimethalin)	12.5 g	11.4 h	10.4 i	11.437 d
Puma super 7.5%EW (Fenoxaprop-p-ethyl)	14.7 e	14.0 f	12.8 g	13.837 c
Deionized water (Control)	18.5 a	17.5 b	16.6 c	17.529 a
Varieties mean	15.51 a	14.63 b	13.83 c	
Year 2022 year 2023				14.62 14.70
LSD $_{(0.01\%)}$				NS
Interactions year × varieties year ×treatments varieties ×treatments				Significance NS NS*

LSD for Varieties (0.01%) = 0.22
LSD for Treatments (0.01%) = 0.28

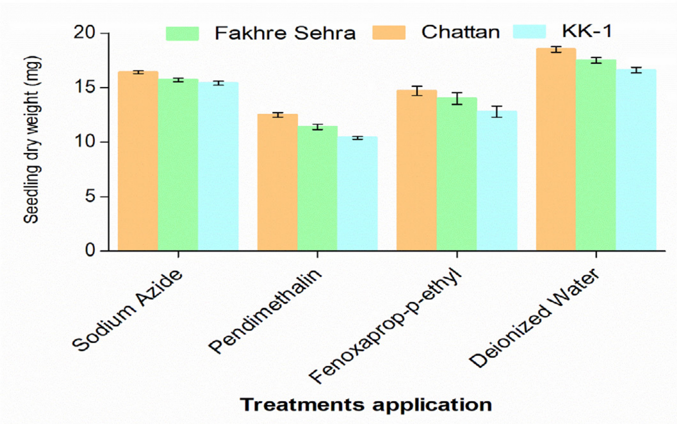

Figure 5: *Interaction of varieties and treatments on seedling dry weight (mg) of chickpea.*

Conclusions and Recommendatoins

Concluded from the current findings that sodium azide had significant effect on seedling growth parameters.

Among the three tested varieties of chickpeas the Fakhre Sehra was found best in terms of seedling growth parameters as compared to Chattan and KK-1.

Sodium Azide showed potential for enhancing chickpea plant development, while herbicides like pendimethalin can be toxic to chickpea plants. For sustainable agriculture, using various weed control techniques with reduced herbicide reliance offers a balanced approach.

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Novelty statement

Current research results highlighted the significance of judiciously evaluating chemical applications and their impacts on crop development. Whereas sodium azide showed potential for enhancing chickpea plant development, herbicides can cause significant plant toxicity and other negative effects. To promote sustainable agriculture, growers should consider implementing various control techniques that reduce herbicide dependency and incorporate diverse control methods, thereby minimizing adverse effects on crop development and productivity.

Author's Contribution

Abdullah: Conducted the experiment, analyzed the data and writing of manuscript.
Muhammad Ishfaq Khan: Revesion of the manuscript.

Generative AI or AI assisted technology statement
The authors have declared that no generative AI or AI-assisted technologies were used to create this manuscript.

Conflict of interest
The author(s) declare(s) that there is no conflict of interests regarding the publication of this article.

Referance

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